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Energy efficient aeration in a single low pressure Hollow Sheet Membrane Filtration Module

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Introduction & Objectives

- Fouling is the main bottleneck of the widespread of MBR systems.
- Process hydrodynamics can decrease and/or control fouling.
  - by adding air and having a 2-phase flow.
- Hollow Sheet (HS) MBR (Alfa Laval) (Fig. 1)
  - Operates with low TMP (~0.03 bar) across the entire membrane surface (MS).
  - Permeate is drained from entire MS.
  - Advantages of low TMP are:
    - MS is less prone to fouling (longer service life)
    - Activated sludge (AS) passing across MS does NOT accumulate/stick to MS.
    - AS flows upwards between the membrane sheets while permeate passes through the MS.
- To ensures that AS circulates properly:
  - Air bubbles are used to create a two-phase cross-flow velocity
  - Bubbles generate scouring effect to remove particles that are attached to MS.

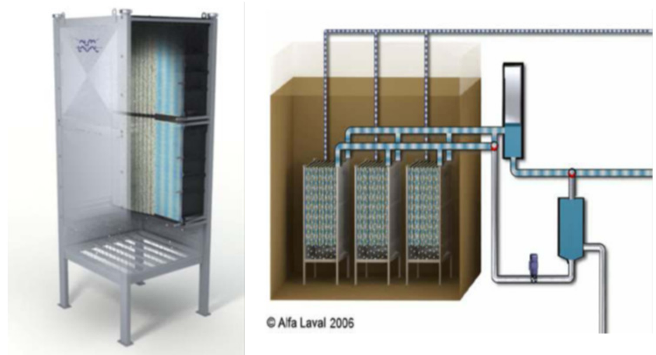

Figure 1. Alfa Laval MBR

Methodology

Velocity measurements

- Single filtration module which has 86 HS polyvinyl membranes (total MS of 154 m^2) (Fig. 2).
- Experiments were conducted at the Danish Hydraulic Institute (DHI) (Fig. 3).
- Experimental velocity measurements were obtained from micro-propellers (MP) between two HS membranes (Fig. 4).
- Air is introduced in reactor through 7 perforated pipes with 7 holes (4 mm) in each pipe.
- Air flow rate in the experiment was 55 and 83 m^3·h^{-1} and CFD model was 37, 55 and 83 m^3·h^{-1}.

CFD model (Fig. 5)

- Ansys CFX v13
- Mixture 2-phase model
- k-ϵ turbulence model

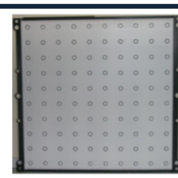

Figure 2. HS membrane

Figure 3. Experimental HS reactor and MP

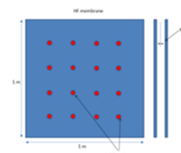

Figure 4. locations of the MP

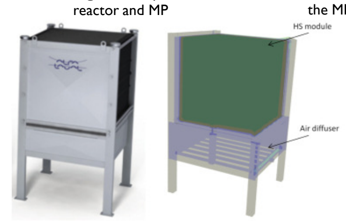

Figure 5. Real and virtual representation MBR module.

Results and discussion

Velocity measurements

- CFD velocity profiles for one HS membrane (Fig. 6).

Air flow rate (m^3·h^{-1})	Experimental (m·s^{-1})	CFD (m·s^{-1})	Error (%)
37*	-	0.198 ± 0.054	-
55	0.218 ± 0.051	0.242 ± 0.065	10.9
83	0.309 ± 0.067	0.292 ± 0.072	5.7

*Experimental measurements were not carried out at this air flow rate

- Air is well distributed within module and no pronounced dead zones were found (Fig. 7).
- A fairly good agreement between the experimental measurements and the CFD simulation regarding the magnitude of the velocity was achieved (error less than 11 %).
- CFD model enabled to provide insight on the velocity profiles and air distribution.

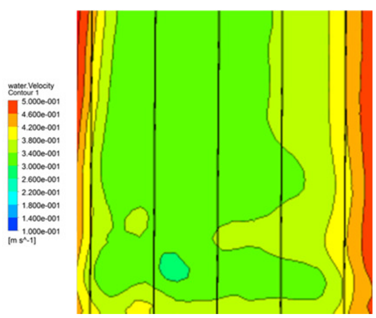

Figure 6. Contour plot of CFD velocities between filtration sheets at an air flow rate of 55 m^3·h^{-1}.

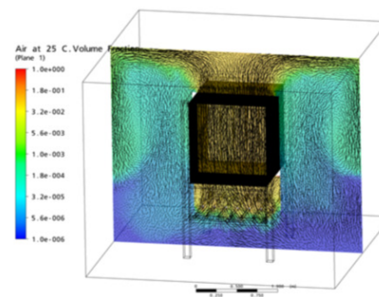

Figure 7. Air volume fraction and velocity vectors for a HS membrane filtration module

Wall shear stress

- It was inferred from CFD simulation that values of the shear stress were accurate (Fig. 8).

Air flow rate (m^3·h^{-1})	CFD (Pa)
37	0.196 ± 0.02
55	0.384 ± 0.02
83	0.464 ± 0.03

- Shear stresses on MS are evenly distributed.

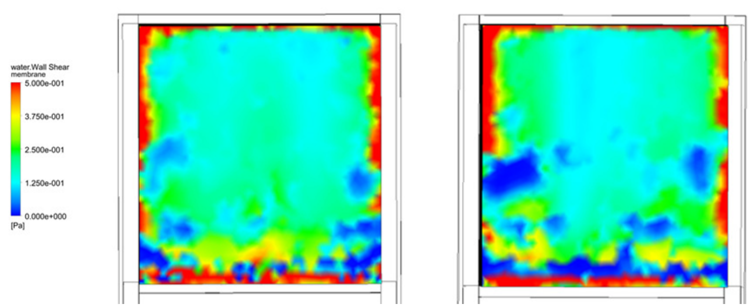

Figure 8. Shear stress profiles for the HS system for an air flow rate of 37 m^3·h^{-1}. Above diffuser holes (left) and between diffuser holes (right).

Conclusions

- A proper validation of the CFD model was made in terms of velocity measurements using MP with water.
- An error less than 11 % was found between experimental measurements and CFD simulations in terms of velocity profiles.
- Wall shear stress was inferred from CFD simulations.
- Shear stress is homogeneously distributes over the HS MS